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EFFECT OF MARINE AIR ON THE FIRECLIMATE IN THE MOUNTAINS OF SOUTHERN CALIFORNIA

y Harry Coffin

Technical Paper No. 39

September 1959

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Pacific Southwest Forest and Range Experiment Station
Berkeley, California . . . . Keith Arnold, Director

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U. S. ~~DEPARTMENT OF AGRICULTURE,~~ FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION 7a

FOREWORD

Fireclimate Studies--Their Purpose

Experience and research have taught fire fighters a good deal about wildland fire. Its general relationship to weather, fuels, and topography is well known. Application of this knowledge to control of fire is frequently hampered by lack of information about the behavior of fireclimate in specific places--how wind, temperature, humidity, and fuel moisture are affected by topography, water bodies, season, and the fire itself. The existing system of weather stations provides enough information for general weather forecasts but not enough to define local fireclimate patterns. The stations are relatively few, widely spaced, and seldom equipped with recording instruments. They gather only momentary samples of weather conditions and provide no information on the way the fire itself affects the patterns.

To obtain this needed information, the Station has started studies aimed at establishing some of the principles controlling local fireclimate patterns and the effect of fire on these patterns. A four-pronged attack will be made on the problem:

1. Semi-permanent fireclimate surveys wherein distinct topographic types will be intensively instrumented for one or more years primarily for the study of variations in local fireclimate patterns in relation to more general weather patterns.

2. Temporary or mobile surveys that will permit exploratory studies of fireclimate patterns around prescribed burns and wildfires and short-term detailed studies of various phases of broader scale fireclimate patterns.

3. Analysis of existing fire and weather records to establish, if possible, the relation of pattern of past fires to weather patterns.

4. Controlled laboratory studies aimed at determination of the fundamental laws governing fireclimate patterns and effects of fire on these patterns.

Project Organization

The research work reported here was part of a semi-permanent fireclimate survey conducted in the Arroyo Seco watershed of the Angeles National Forest in southern California. This phase of the project was supported by a grant from the U. S. Forest Service under the terms of a Student Cooperative Aid Agreement between the Forest Service and the University of California. The work was performed by Harry Coffin under the direction of the Department of Geography of the University and the Forest Fire Research Division of the Pacific Southwest Forest and Range Experiment Station.

ABSTRACT

During the summer months marine air penetrates into the interior of southern California to a greater or lesser extent depending upon the air flow patterns of the general circulation of the atmosphere. There are seasonal variations in the strength of the marine influence, a maximum in late June and early July and a minimum in August and early September. These variations are also associated with changes in the general circulation, and the poleward contraction and equatorward expansion of the belt of the westerly winds.

The relatively cool, moist marine air tends to reduce forest fire danger by increasing the moisture content of fine fuels. During spells of strong marine influence, called Catalina Eddy circulation, there is a lower incidence of major forest fires in the wildlands of southern California. Further, local circulations within the mountains are upset by the strong inflow of marine air. The diurnal mountain-valley wind system is replaced by winds blowing day and night from the lowlands to the highlands.

The marine influence is widespread and extends to high elevations. All of the seaward parts of southern California are affected.

TABLE OF CONTENTS

Page

THE CATALINA EDDY 1

INTENSITY AND FREQUENCY OF EDDY CIRCULATION 4

ASSOCIATED DAILY WEATHER RECORD 6
    Local Winds 6
    Temperature 8
    Humidity 9

ASSOCIATED FOREST FIRE OCCURRENCE 9

SOME RELATIONS BETWEEN THE COASTAL INVERSION AND MOUNTAINOUS TERRAIN 11

CONCLUSIONS 16

APPENDIX 17

EFFECT OF MARINE AIR ON THE FIRECLIMATE IN THE MOUNTAINS OF SOUTHERN CALIFORNIA

Harry Coffin,
Assistant Professor of Geography[1]

The research project covered by this report was undertaken to determine the extent of the penetration of marine air into the interior of southern California and the degree to which the daily weather is influenced by the relatively cool, moist air. The areas to be considered are those mountainous areas bordering the Los Angeles Basin, although the seaward parts of all the mountains of southern California will receive some attention. The presence or absence of marine air in forest lands can be of real importance to the summer fire danger and fire fighting problems. It was the purpose of this study to determine the relationships between marine air and those problems as well as to discover possible parameters that might aid in forecasting weather conditions associated with the advection of maritime air.

The data used in the study have come from the U. S. Weather Bureau, the U. S. Forest Service, and from the two-year Fireclimate Survey conducted in the Arroyo Seco drainage of the San Gabriel Mountains by the Forest Fire Research Division of the Pacific Southwest Forest and Range Experiment Station. Many of the data are unpublished and were derived from original records.

The interest of the Forest Service in problems of this sort stems from the need to know more fully the climatological and meteorological parameters entering into the general behavior of fire on wildland. It was hoped that the study would return this type of knowledge and that some of the findings, at least, would result in a better understanding of sub-tropical, dry-summer climates.

The Catalina Eddy

Early in the study it was noted that there were rather wide fluctuations in the humidity of the air in the interior of southern California. A search of the literature revealed that this phenomenon was known to meteorologists, that it had been named, and that techniques for forecasting the changes had been worked out.

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The so-called Catalina Eddy is a summertime phenomenon long recognized by southern California forecasters. It received its name because it was first conceived as a mechanical eddy system set up in the prevailing northwest flow of air along the coast of southern California. It was believed that the Santa Inez Mountains, which terminate at Pt. Conception, produced a shallow low-pressure area centered near Santa Catalina Island in the large embayment south and east of Pt. Conception. This shallow depression was supposed to generate a cyclonic circulation producing moderately strong winds having a south component all along the coast from the vicinity of the Palos Verdes Hills southward. The hypothesis of the existence of an eddy was set up to explain the rather frequent occurrences of such southerly winds that have been observed along the coast as far south as Ensenada in Baja California. In fact, one of the important parameters used to determine the presence of the circulation pattern is the occurence of southerly winds at San Diego.

The postulate that the pattern is a mechanical eddy formed in the lee of the Santa Inez Mountains is entirely inadequate to explain a circulation covering thousands of square miles. In further work on the phenomenon, the summertime thermal low-pressure area, which lies persistently over the Colorado and Mojave deserts to the east and northeast, was invoked as the mechanism producing the increased on-shore flow of air. The pressure difference between coast and desert may well contribute to the strength of the circulation, but it is insufficient to explain the sequence of occurrences of the phenomenon, as will be demonstrated later.

The Catalina Eddy has been variously defined. Meyer's definition[2] may be taken as illustrative of the consensus of meteorologists presently concerned with the phenomenon: "The eddy is a small low pressure area centered somewhere within the rhomboid figure defined by San Diego, San Nicholas Island, Pt. Conception, and Ontario, but typically the center is near Santa Catalina Island." There seems to be no agreement, however, on the various phases of an eddy, nor the degree of cyclonic curvature required before a circulation pattern can be called an eddy, nor the velocity of wind within the system, nor the height to which the eddy circulation is effective. Graham[3] recognizes six types of summertime circulation patterns ranging from one that is almost directly opposite to an eddy circulation, i.e. one in which south or southeast winds are observed at Pt. Arguello, through increasingly strong eddy development, to a pattern of intense

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[2] Meyer, R. R. Forecasting the Catalina Eddy. U. S. Weather Bureau Forecast Center, Los Angeles. 1955. (Unpublished research report.)

[3] Graham, R. D. Divergence-vorticity of the southern California coastal winds. U. S. Weather Bureau Airport Station, Los Angeles. 1950. (Unpublished research report.)

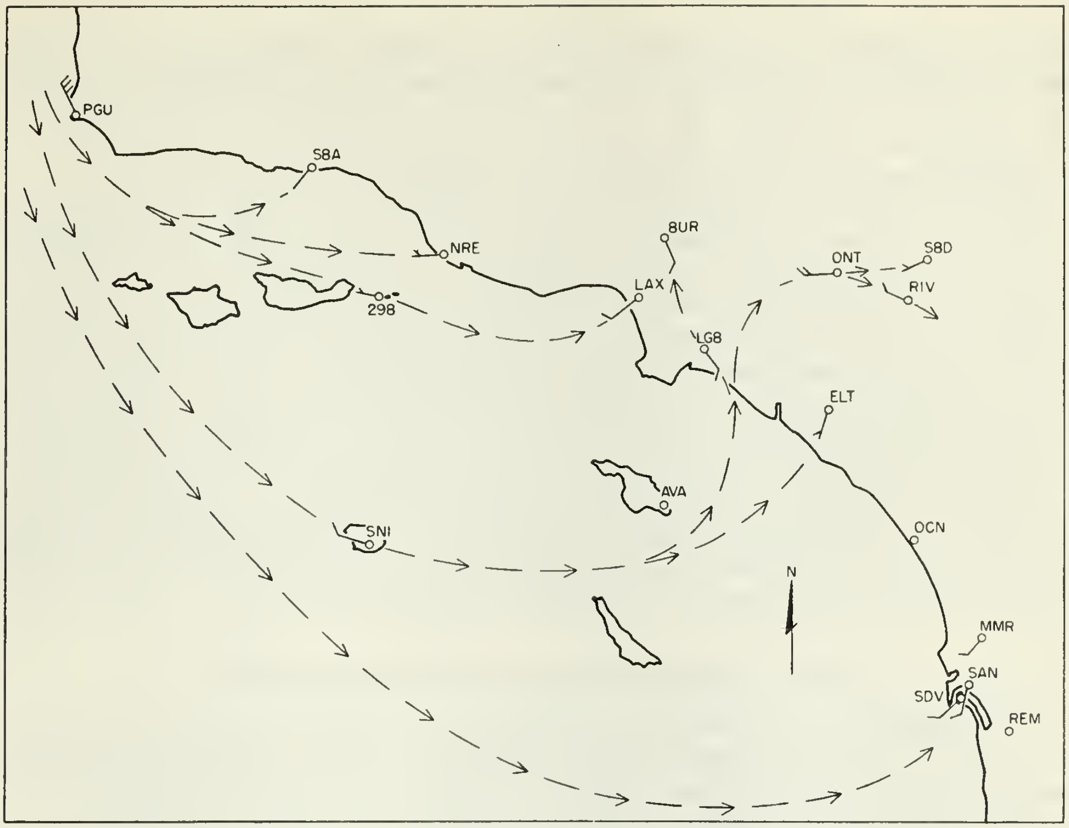

Figure 1.--Typical Catalina Eddy circulation.
August 24, 1956, 1630 P.s.t.

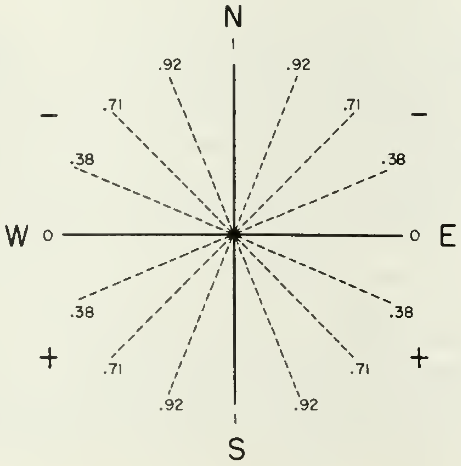

Figure 2.--Diagram showing
method of determining
vector sums.

eddy circulation with strong southerly winds observed well down the Pacific coast. According to Graham's system of circulation types, the winds at San Diego are not necessarily affected by weak eddy circulations, although he uses the south component in the wind at San Diego as the most important and simplest indicator of the existence of an eddy circulation.[4] There is an observed relationship between the strength of the eddy circulation and the height of the marine inversion or the thickness of the marine layer. Meyer states: "A developing eddy tends to lift the base and top of a stratus cloud and to carry it farther north and farther inland than would be expected from non-eddy considerations." As it is not the purpose of this report to develop a precise and complete definition of the Catalina Eddy in all its forms, but to determine the effects of the penetration of marine air into the interior of southern California, we will consider here only those cases of eddy development that are strong enough to affect the wind direction at San Diego and hence those capable of supplying large quantities of maritime air to the mountainous areas of southern California.

Intensity and Frequency of Eddy Circulation

Streamlines show the pattern of air flow at the surface over the ocean and the adjacent coast during a time of well-developed Catalina Eddy circulation (fig. 1). The winds have a strong cyclonic curvature, and a southerly component is observed along the south coast at least as far south as Ensenada. This southerly component has been used as an important indicator of the existence of an eddy circulation, the wind at San Diego being used. In order to determine both the intensity of the circulation and frequency of its occurrence during the summer, the hourly observations of wind speed and direction at San Diego for the months May through October of the years 1948 through 1957 were analyzed.

Each observation was transformed into a vector quantity in the following way: The direction of windflow is defined by the sine of an angle generated by rotation from an east-west line. The signs of the values are changed so that values in both southern quadrants have a positive sign and values in both northern quadrants a negative sign. The values are then multiplied by the wind speed to arrive at the vector quantity. This is a purely conventional method, but one that serves to distinguish the southerly and northerly components (fig. 2). The 24 vectors for each day are then summed algebraically and these vector sums plotted on daily graph paper (figs. 7 through 17). In these figures the sums are plotted above and below a zero value line that represents a balance during the 24-hour period between north and south components. If the south component is stronger, giving a positive vector sum, the value is plotted above the zero line. If the north component is stronger, giving a negative vector sum, the value is plotted below the line.

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[4] Graham, R. D. The effect of the Catalina Eddy on the summer wind at San Diego. U. S. Weather Bureau Forecast Center, Los Angeles. 1955. (Unpublished research report.)

Two very striking features of these graphs are immediately evident. The first is the seasonal variation in the wind. There is a maximum frequency and intensity of south components in late June. The north component is stronger in late August and early September. Although there is variation from year to year, this seasonal tendency is sufficiently strong to appear in a combination of the ten yearly graphs (fig. 17). This combination is derived by summing alegebraically for each day the ten daily vector sums. The overlaid curve in figure 13 is a 10-day moving mean. The first three months of the summer season generally experience a quite different type of wind regime from that of the last three months. There is a greater number of instances when the wind is southerly during the first half of the season. Furthermore, the velocity of the southerly winds is greater at that time than during the second half of the season.

To return to the yearly graphs, the second important feature is the aperiodic repetition of spells of predominantly southerly winds. These spells vary in length from 2 to 7 days, and can occur at any time during the summer season, but the greater part occur in June and July. The varying lengths of these spells and their spacing in time is very suggestive of the movement of waves in the belt of the westerly winds. With the hypothesis in mind that the spells of southerly winds at San Diego are but the surface expression of a much larger circulation pattern, various maps and charts have been consulted to see if, in fact, there is some relationship between this local phenomenon and the general circulation.

The surface synoptic weather map proves to be too affected by a multitude of local influences to be of much help. The 700 millibar upper air chart gives a better picture of the general air flow; and here barometric depressions appear at the proper times to account for the southerly component in the winds at the surface. As is to be expected, the relations are not entirely clear, for several kinds of pressure patterns are associated with the southerly component. These different kinds of pressure patterns show up more clearly on the 500 millibar constant pressure chart.

They can be separated roughly into two general types. The first and most frequent is a trough aloft that passes from west to east. Apparently it is not necessary for the axis of the trough to extend as far south as southern California for its effects to be felt at the surface although many troughs do reach that far south. The second major type pattern is one in which a high pressure cell centered near the boundary between Arizona and New Mexico develops over the Southwest. Winds blowing out of this high have a southerly component on the western side of the cell and probably extend down to the surface, accounting for the southerly winds there. The physical and temporal relationships between disturbances in the westerlies and variations in local winds have not been worked out, but at this time it seems that the clues to the solution of the problems of local weather changes lie in these relationships.

There can be little doubt that the spells of southerly winds along the southern California coast are a response to changes in the pressure distribution in the westerlies and that these changes serve as the mechanism for the increased inflow of marine air into the interior. The surface pressure difference between coast and interior generated by the intense heating over the desert areas may well contribute to the strength of the flow, but cannot be invoked as a cause. A medial association test of the observations made in 1957 indicates no significant association between the difference in sea level pressure Los Angeles minus Daggett and the north-south wind components at San Diego. There are, however, strong positive associations between the north-south components at San Diego and air moisture content and temperature at many places in and around the Los Angeles Basin.

Associated Daily Weather Record

An increase in the volume of marine air flowing into the interior parts of southern California should bring noticeable changes in the daily weather observed at inland stations. Such is the case. Local winds, temperature, and the moisture content of the air, with an associated increase in cloudiness, are all affected by the change in air movement.

Local Winds

In the Arroyo Seco drainage of the San Gabriel Mountains where fairly detailed weather observations were made during the summers of 1956 and 1957, it is possible to delineate with some accuracy the locally observed effects of a period of moderately strong inflow of marine air. The San Gabriel Mountains, an east-west trending range, rise abruptly from the plain of the Los Angeles Basin with steep slopes along their front. This front wall is broken by numerous canyons, that of the Arroyo Seco being of moderate size. This canyon is open to the south with direct access to the plain. Hence it is in an ideal situation for the development of mountain-valley winds, and such winds are common phenomena in the canyon; daytime, up-canyon winds alternate with nocturnal, down-canyon winds. Slopes within the Arroyo Seco are steep, and the relatively low vegetation cover (chaparral) permits rapid heating of the slopes and thus facilitates the development of slope winds. One site within the canyon, designated as station 07, (location of fireclimate stations are shown in figure 18) is situated on an east-facing slope at an elevation of about 2,300 feet, roughly a third of the way up the canyon side from the bottom. It receives the early morning sun and is in shadow fairly early in the afternoon. Here a typical rotation of wind direction develops during the day as upslope winds give way to up-canyon winds, which in turn become downslope and then down-canyon winds.

Figure 3 is a chart showing two-hourly wind observations at station 07 from August 21 through September 2, 1956. The date is on the left side of the chart and the times of the observations are across the bottom. The arrows and numbers within the small blocks denote speed and direction of the wind. North is at the top. The part of the chart that is heavily outlined represents the period during which the wind at San Diego had a southerly component. The chart is intended to depict primarily the changes in nocturnal winds in response to a so-called Catalina Eddy circulation.

With the onset of the system, there is a slight increase in the speed of the up-canyon daytime winds as the inflow of marine air augments the normal thermal up-canyon flow. The most striking feature of the chart is the up-canyon flow at night that begins on the night of August 26 and continues for two nights. The flow of air into the Los Angeles Basin apparently is strong enough to penetrate into the mountain areas adjoining and to reverse the normal down-canyon nocturnal drainage. There is also implied here a considerable deepening of the marine layer, the result of which is a more nearly homogeneous layer to greater heights than is found when the marine layer is shallow. This is to say that temperature and humidity differences between the plain and the mountain crests are reduced, so that the opportunity for thermal winds to develop is diminished.

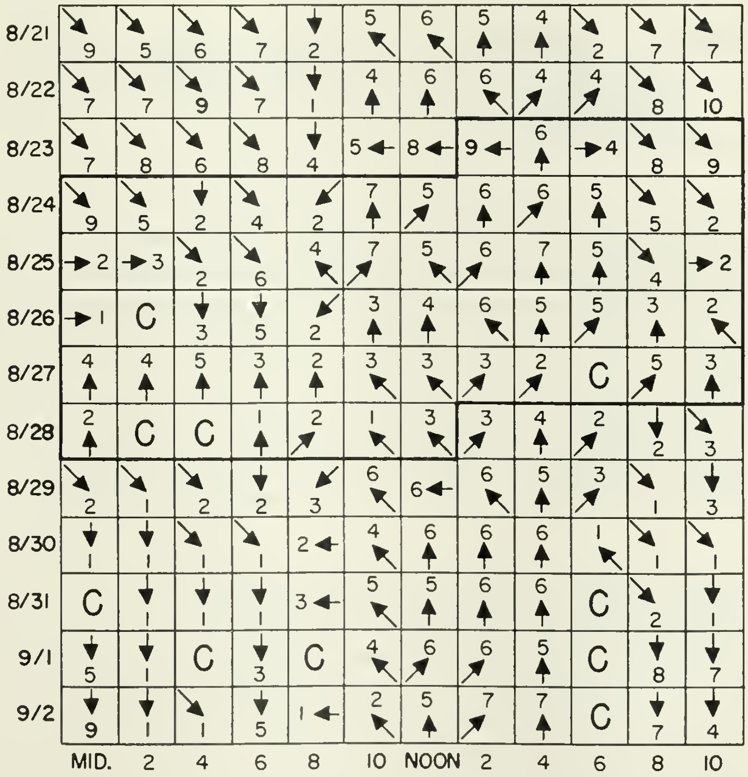


Figure 3.--Wind observations at station 07, August 21-September 2, 1956.

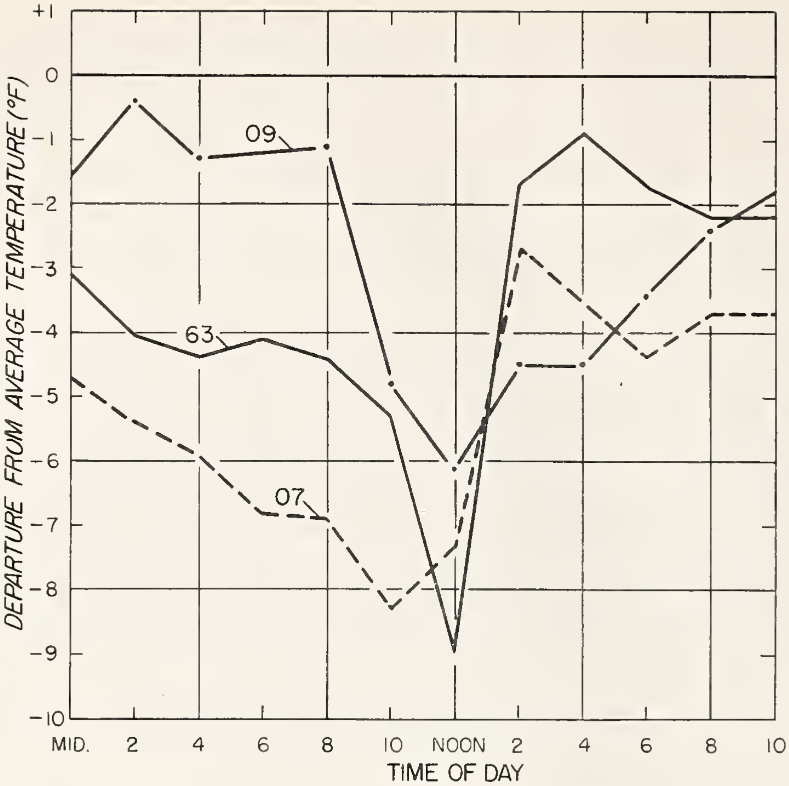


Figure 4.--Average departures of temperatures from means at three stations for days with strong south wind at San Diego during summer of 1956.

Temperature

When marine air penetrates into the mountains, there are marked changes in temperature (fig. 4). The observations made at each of three stations in the Arroyo Seco during the summer of 1956 were averaged, and the average departures from those means during days of strong south wind at San Diego are plotted in figure 4. At all times of day, lower temperatures were observed at all stations, the greatest differences being found at 1000 and 1200 P.s.t. These large temperature differences may best be explained by a change in air mass; that is, by air from a different source region.

It is significant that the highest station (63, at 4,650 feet) shows the largest change, while the lowest station (09, at 1,650 feet) shows the smallest. Station 09 is more frequently under the influence of marine air than is station 63, and station 63 is generally under the influence of relatively dry and warm continental air. Consequently the change at the higher place is more pronounced as a result of the change from continental to marine air mass. This one example suggests that the largest differences in temperature between days when the marine influence is strong and days when it is weak or absent are to be found at those places that are marginal to the Los Angeles Basin rather than at places nearer the ocean.

Humidity

Table 1 shows the pairwise correlation coefficients of relative humidity at 1630 P.s.t. at 11 stations in southern California. All correlations are positive and all but one are significant at the .01 level. The correlation of .22 between Ojai and Butler Peak is significant at the .05 level. In the table the stations are listed according to their average correlation coefficients from high to low. With the exception of Descanso, those stations that are farthest away from what might be considered as the core area--the Los Angeles Basin--have the lowest correlations.

It is, of course, to be expected that stations situated relatively near one another should be similarly affected by changes in the weather. The important fact demonstrated in table 1 is that stations situated far from one another either horizontally--as Descanso and Ojai--or altitudinally--as Butler Peak--may also be similarly affected by weather changes. There is a strong suggestion from this relationship that all of the seaward parts of southern California simultaneously experience rather far-reaching weather conditions and that these conditions result from something other than local causes.

Associated Forest Fire Occurrence

Of some practical importance is the relationship between marine air inflow and the start and development of major forest fires in southern California. If, as has been shown, alternations between air masses produce the observed meteorological effects throughout much of southern California, conditions favorable to intense forest fires would also be affected. The so-called "fine fuels" in a forest--grass, twigs, and forest litter--are exceedingly responsive to changes in the relative humidity of the air. They take up and lose moisture very rapidly, and it is in these light, easily combustible fuels that fires most readily start. For the purposes of this study, major fires are defined as those that burn 100 acres or more. The fire records of the U. S. Forest Service were examined and the dates of the starts of all major fires were extracted for the years 1948 through 1957. Only the months May through October were used; many large fires occurring during so-called Santa Ana conditions, which are a special case that need not concern us here, are thus excluded.

The records come from four southern California National Forests: the Cleveland National Forest, the San Bernardino National Forest, the Angeles National Forest and the southern districts of the Los Padres National Forest. Consequently, a large part of the mountainous area of southern California is covered by the reports.

The date of the start of each fire was tabulated according to whether it fell on a day with a positive (southerly) or negative (northerly) vector sum at San Diego. The number of fires in each of these two groups was divided by the number of days in the group

Table 1.--Correlation coefficients of 1630 P.s.t. relative humidity at 11 southern California stations

Station	Lytle Creek	Cajon Summit	Tanbark	Banning	Strawberry Peak	Descanso	Highline Lookout	Perris	Butler Peak	Valyermo
Cajon Summit	.99	--	--	--	--	--	--	--	--	--
Tanbark	.80	.84	--	--	--	--	--	--	--	--
Banning	.80	.84	.81	--	--	--	--	--	--	--
Strawberry Peak	.77	.82	.83	.86	--	--	--	--	--	--
Descanso	.87	.70	.78	.80	.71	--	--	--	--	--
Highline Lookout	.72	.77	.83	.69	.77	.65	--	--	--	--
Perris	.80	.71	.75	.67	.56	.70	.55	--	--	--
Butler Peak	.66	.65	.65	.77	.78	.66	.54	.45	--	--
Valyermo	.60	.62	.53	.67	.72	.53	.48	.40	.79	--
Ojai	.70	.62	.72	.61	.58	.62	.69	.73	.22	.26

to provide a common base for comparison. The fire occurrence rate for the positive vector sum group was .075 major fires per day as compared with .098 fires for the negative vector sum group. Thus there were 1.31 times as many fires on days with northerly air flow at San Diego than on days with a southerly flow. At least part of this result may be explained by the almost immediate effect of an increase or decrease in the relative humidity on fine fuels. When the humidity is very low, as it tends to be on days with a northerly component, fires spread much more rapidly for the same wind speed than when relative humidity is high.

A further examination of Forest Service fire records to determine the incidence of lightning-caused fires in the four southern California forests as related to wind direction at San Diego, shows a relationship opposite to that of major fires. On all four National Forests there is a higher percentage of incidence of lightning fires on days when the wind is south at San Diego than when the wind is north. Lightning fire occurrence for northerly winds was .224 per day while the rate for southerly winds was .371 or 1.66 times as great.

Thunderstorms (and lightning fire incidence) are usually associated with moist air aloft in southern California. This air is most often brought in by southeasterly flow aloft and hence may well be associated with a southerly component at San Diego.

Some Relations Between the Coastal Inversion and Mountainous Terrain

The upper surface of the marine layer of air that penetrates into the interior of southern California is marked by a temperature inversion that varies in intensity as the relative temperatures of the two air masses. This temperature inversion forms an extremely stable boundary layer that is an effective barrier to convection originating beneath it.

I had observed on several occasions during the summer of 1957 that the smog over the Los Angeles Basin invaded the canyons of the San Gabriel Mountains more strongly at certain times and that it was markedly layered in appearance. It seemed possible to record the movement of the smog photographically and so I took a series of pictures of it during one entire day (fig. 5). The camera was set at a site that gave a good view of the south face of the mountains. The location was at 3,000 feet elevation. The camera was level and was pointed 15° south of east. The pictures were taken every hour beginning at 0500 P.s.t. and continued until 1700 P.s.t. on August 10, 1957.

During the night and the early morning hours, the Los Angeles Basin was covered with a stratus deck which, in the foothill areas, was at the surface at about 1,200 feet. The stratus broke up shortly after 0800. By 0700 there was visible a layer of smog the top of which was at 3,000 feet. From that time on, the smog thickened, and after 0900, began to ascend slowly. Throughout the middle of the day, the smog was extremely heavy and was well above the local mountain summits. At 1500 the smog was thinning slightly and some cumulus build-up over the San Bernardino Mountains, some 60 miles away, was partly visible. By 1600 clearing had progressed considerably and by 1700 the air above 3,000 feet was very clear and a sharply defined inversion was again visible.

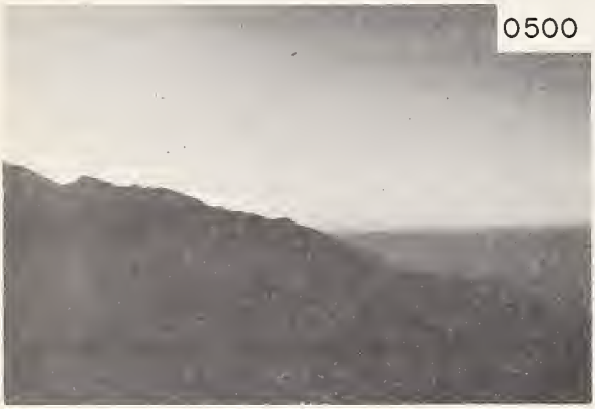
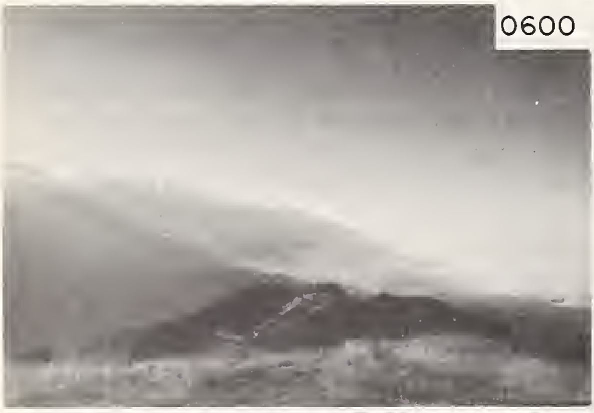
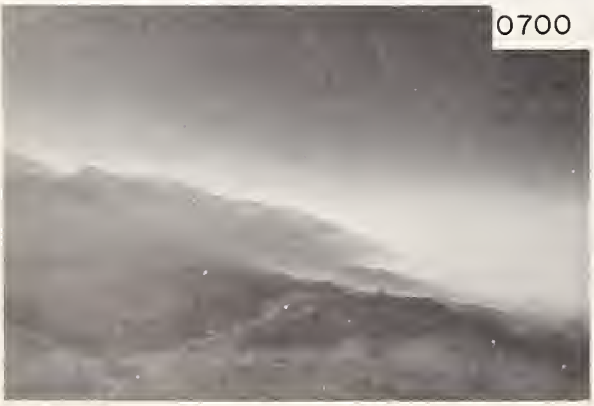
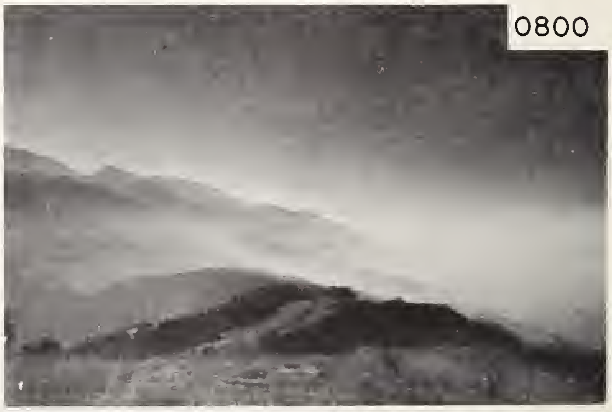
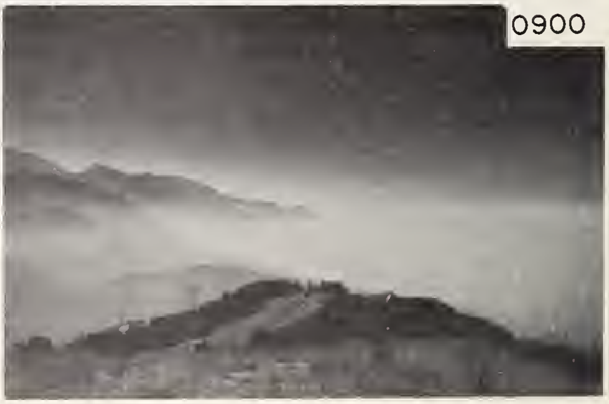


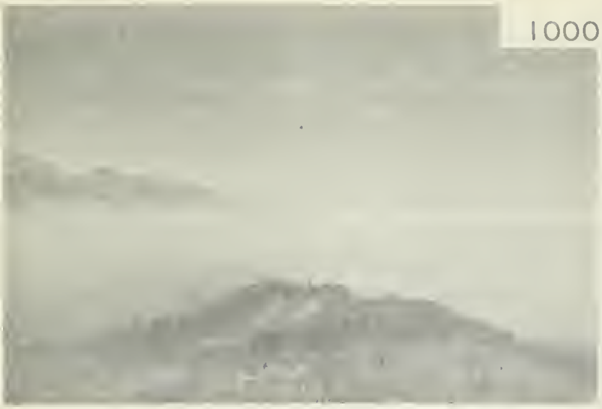
Figure 5.--Smog movement 0500 to 1700 P.s.t., August 10, 1957.







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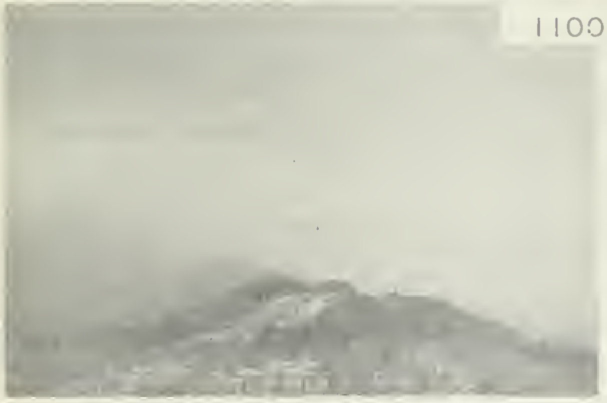
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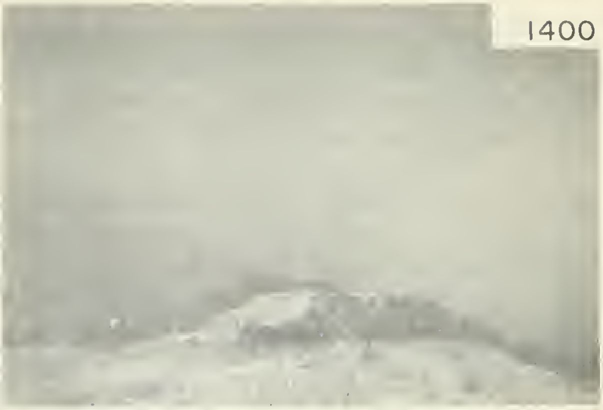
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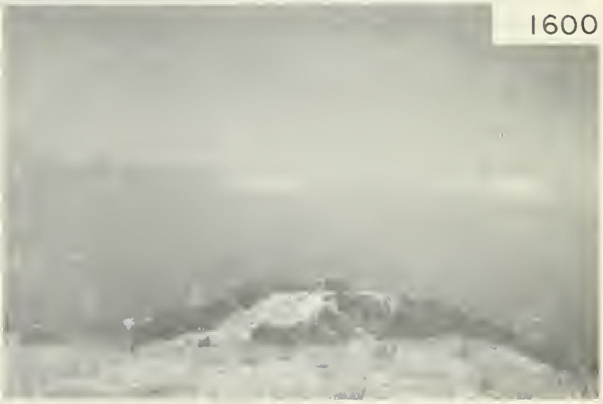
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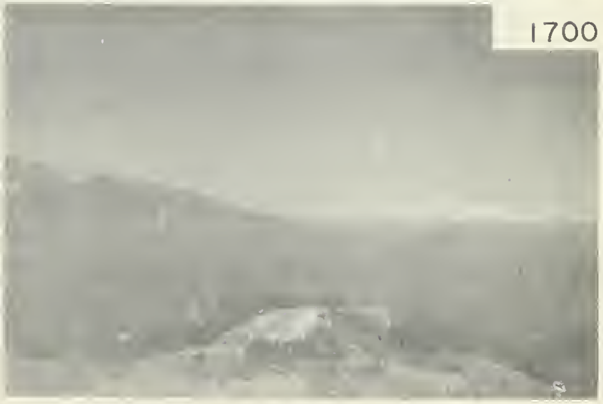
1700

The series of photographs raises some very important questions relative to the problems of the penetration of marine air into the southern California mountains. One of these questions concerns the apparent large vertical movement of the top of the haze layer.

If the top of the haze layer in the early morning coincides more or less with the temperature inversion and the haze layer fluctuates so widely during the day, what mechanism can be called upon to explain the movement? That the movement is related to diurnal variation in heating and cooling is evident, but in what way? I doubt if it can be explained on the basis of advection of a large volume of cooler marine air because the upward movement begins inland well before a sea breeze begins to blow at the coastline. It is more likely that heating of the mountain slopes begins shortly after sunrise and that upslope and up-canyon winds begin to blow. This contention is borne out by observation. The heating of the air under the inversion, particularly in the mountains where the inversion is at the surface, works to cancel it both by turbulent mixing and by a change in the lapse rate. With the establishment of an adiabatic lapse rate from the surface upward and with the upslope winds, the contaminated air in the basin can be carried away. This phenomenon is of great importance to people living in the basin as well as for the purposes of this study as it indicates the transportation of marine air into the mountainous areas bordering the plain. The smog makes it possible to observe atmospheric phenomena simply that otherwise would be difficult to measure.

As air trapped beneath the stable layer of the inversion is drawn out from the basin upward along the mountain slopes, there should develop a deficit in the volume of air beneath the inversion that would not be made up until the marine layer was replenished later in the day with the onset of the sea breeze. This drawing off of air results in a slight concavity of the surface of the inversion layer out over the basin--a condition frequently observed.

The air that is carried into the front country of the San Gabriel Mountains by the upward movement associated with the cancellation of the inversion has a different origin from that of the air above the inversion and would be expected to have different characteristics. This assumption is supported by data from station 10 where, on the date of the photographs, the 0700 temperature was 71° F. and the relative humidity was 32 percent. The 1400 temperature was 92° F. while the relative humidity at that time was also 32 percent. Doubtless some of the increase in air moisture can be explained by increased transpiration of vegetation and by increased evaporation from the soil. However, some large part of the increase must be a result of advection of partly modified marine air, especially since stratus development was strong earlier in the day a very short distance away.

Figure 6 shows the dew point temperatures for three stations in the Arroyo Seco drainage. Station 01 is situated at the mouth of the canyon at an elevation of 1,075 feet. Station 10 is on the western edge of the drainage at an elevation of 3,025 feet. Station 15 is in a saddle near the center of the drainage at an elevation of 2,925 feet. The wind observations made at station 10 on August 10 are also in the figure. The trends of the dew points at the two higher stations, compared with the trend at the lower station, suggest that the increase in air moisture content is largely a result of an advective addition of moisture rather than an addition through evaporation from the soil and accelerated transpiration by the vegetation. The difference in the air at the higher level stations between day and night indicates air masses of different origin; the one from below and from the ocean, the other from above and from the desert.

The daily history of the inversion, at least near the mountains, appears to be as follows: In the early morning hours the inversion is sharply defined, with air masses of quite distinct characteristics above and below the boundary. Before heating begins, the inversion meets the mountain slopes in much the same way that a body of water meets the shore with a minimum of mixing between the stable layer and the air above. After heating begins, upslope winds, turbulence, and warming of the inversion layer destroy the inversion at an increasing distance from the mountain face. This process continues until the time of maximum temperature. By that time the sea breeze has developed, bringing in a new supply of cooler

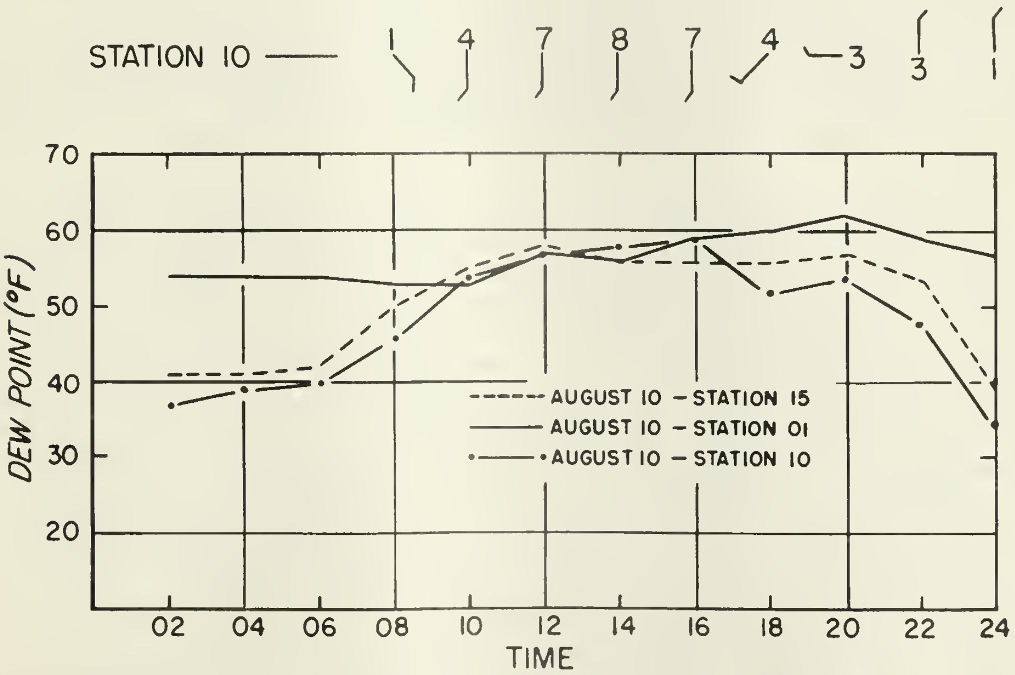

Figure 6.--Wind at station 10 and dew point temperatures at stations 01, 10 and 15, August 10, 1957.

marine air. As surface heating lessens, this new air is cooler than the modified marine air remaining from the morning, and underrides it, forming a new inversion. It is this late afternoon inversion that remains through the night and appears as the sharp inversion observed in the early morning. Cool air moving downslope and downcanyon at night also adds to the pool of low-level cool air. No observations are available on the behavior of the inversion out over the basin at a distance from the mountains, but it is unlikely that it is cancelled out the way it is near the mountains where it is at the surface.

August 10, 1957 was a day of moderately strong Catalina Eddy circulation, which fact explains the presence of the stratus cover that extended at least through the San Gabriel Valley section of the Los Angeles Basin. Apparently Catalina Eddy circulation need not reverse the diurnal wind regime in the mountains for the effects of the marine air to be felt far inland and at high elevations. The local circulations within the mountains resulting from solar heating, and the destruction of the temperature inversion near the mountain slopes are sufficient to start the transport of marine air into the mountainous interior. If the marine layer is deep in the early morning, as it is in the case of a Catalina Eddy circulation, the moist air will be carried into the mountains earlier in the day than it would be under other conditions.

Conclusions

Some fairly definite conclusions can be drawn from the preceding discussion. These are concerned with the reality and the effects of the penetration of marine air inland. On the other hand, some very important questions are raised regarding the relationships between local weather phenomena and the general circulation of the atmosphere, as well as more specific questions about the degree of effect of marine air upon fuels and burning conditions.

Among the things that can be said with some sureness about marine air penetration are: 1. The maritime influence, in all the seaward parts of southern California at least, is real and on frequent occasions is widespread and of considerable depth. 2. There is a distinct seasonal variation in the frequency and intensity of the penetration of marine air. The seasonal minimum of marine influence coincides with the seasonal temperature maximum which suggests that the two are related. In this connection, an investigation of the seasonal zonal changes in the belt of the westerlies should prove most fruitful. 3. Maritime air in southern California appears to have an effect upon the development of large forest fires, with a smaller incidence of such fires during the critical months on days when the marine influence is strong. These relations need to be further studied to determine the relative weights to be given various other factors of a non-meteorological kind, such as available man power for fire suppression, accessibility of the site of the origin of a fire, and the type of terrain, and the types of fuels available for burning.

APPENDIX

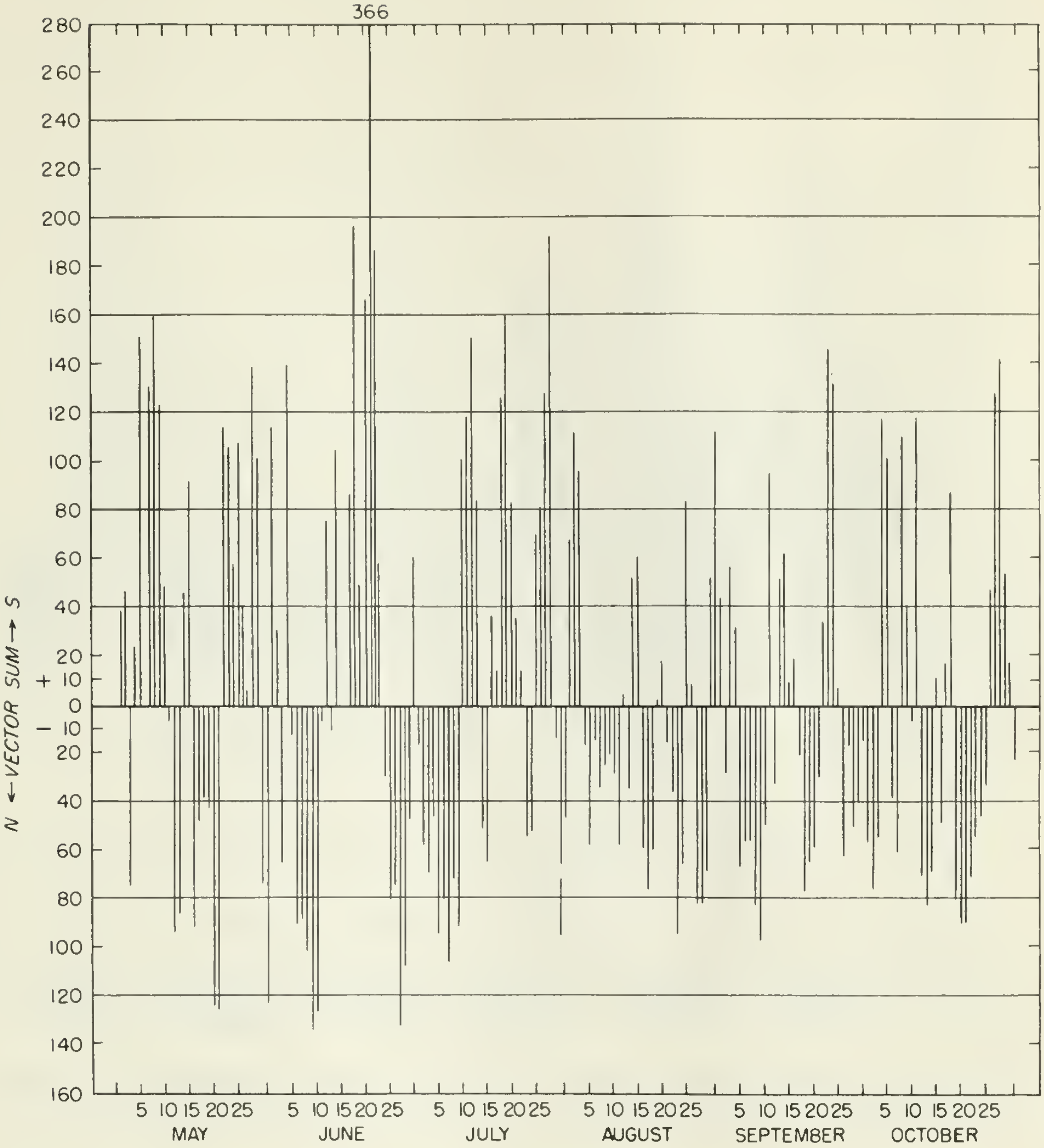

Figure 7.--Algebraic sum of hourly north-south wind components at San Diego for 1948 season.

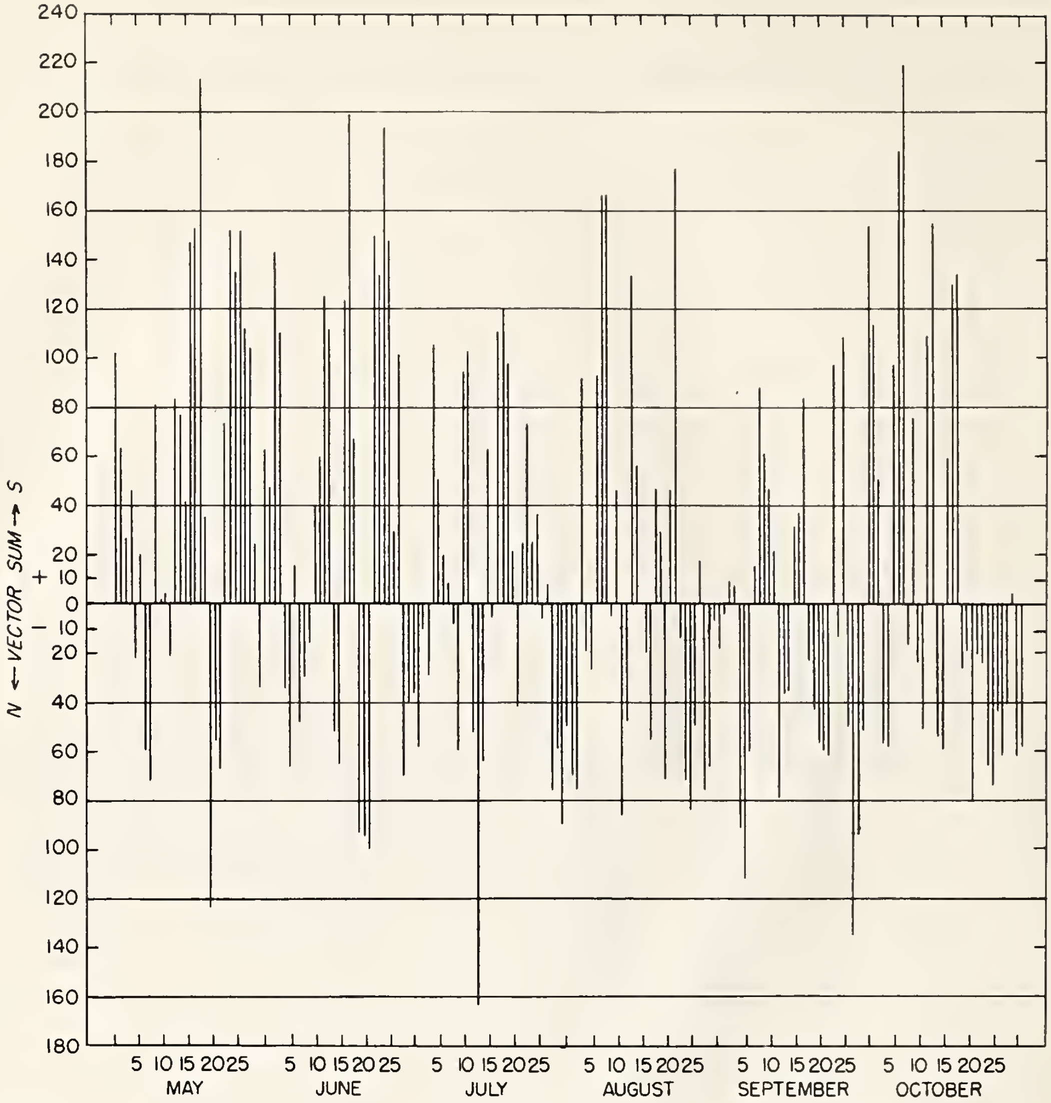

Figure 8.--Algebraic sum of hourly north-south wind components at San Diego for 1949 season.

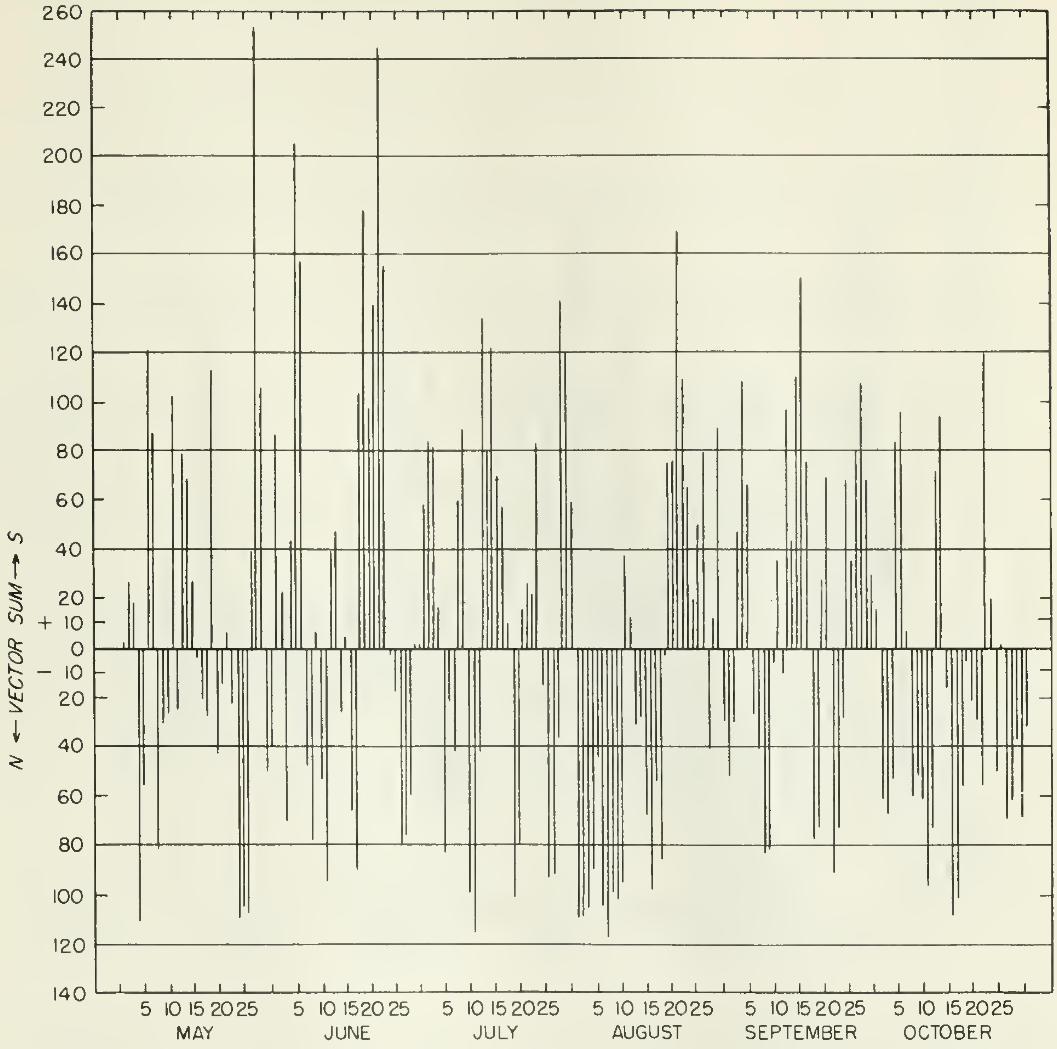

Figure 9.--Algebraic sum of hourly north-south wind components at San Diego for 1950 season.

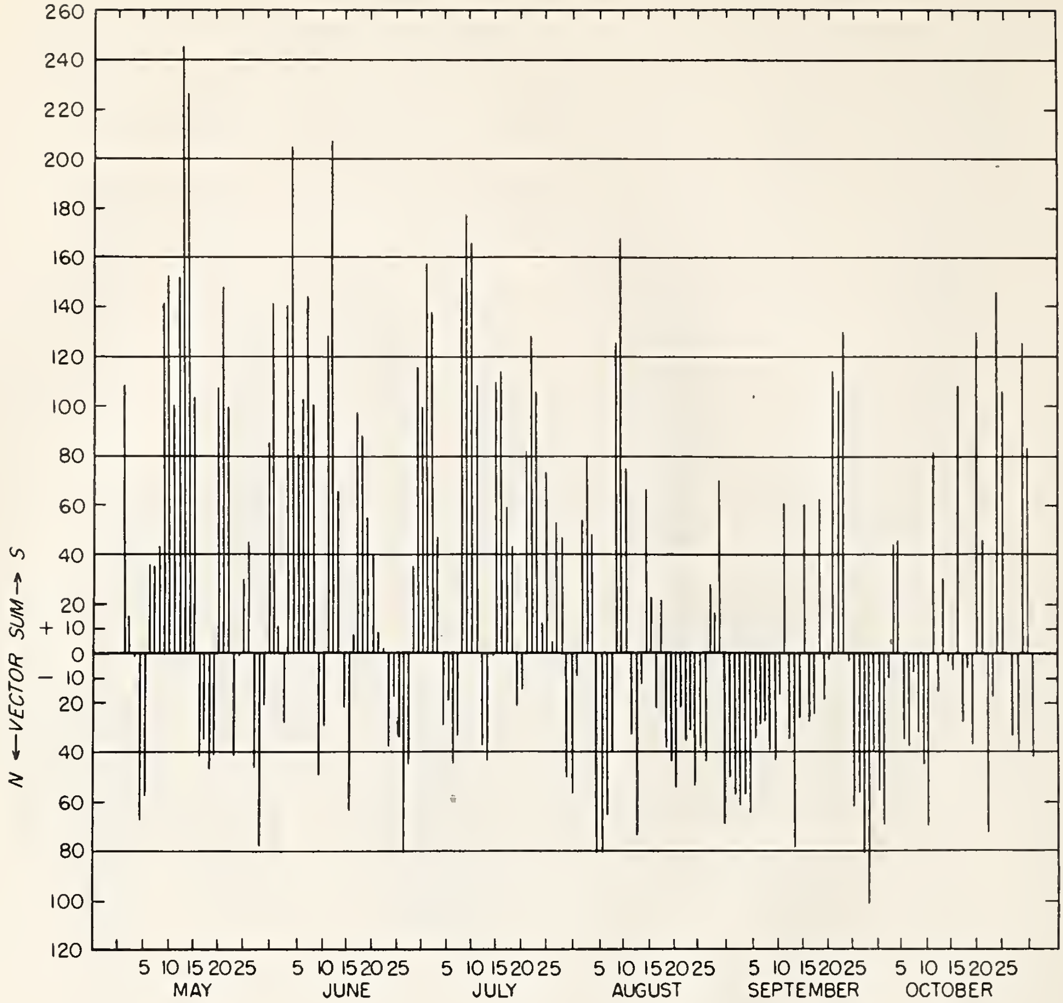

Figure 10.--Algebraic sum of hourly north-south wind components at San Diego for 1951 season.

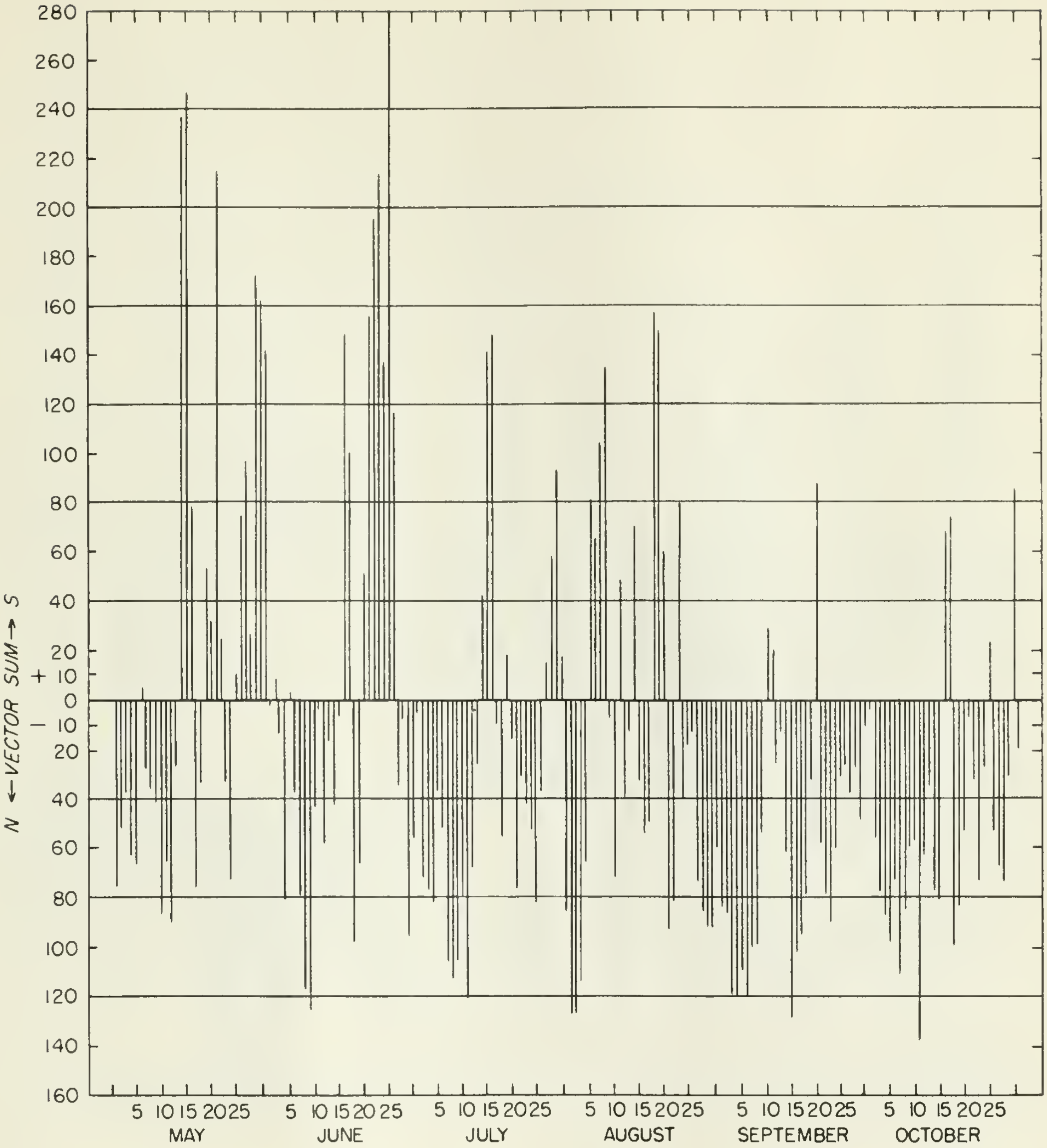

Figure 11.--Algebraic sum of hourly north-south wind components at San Diego for 1952 season.

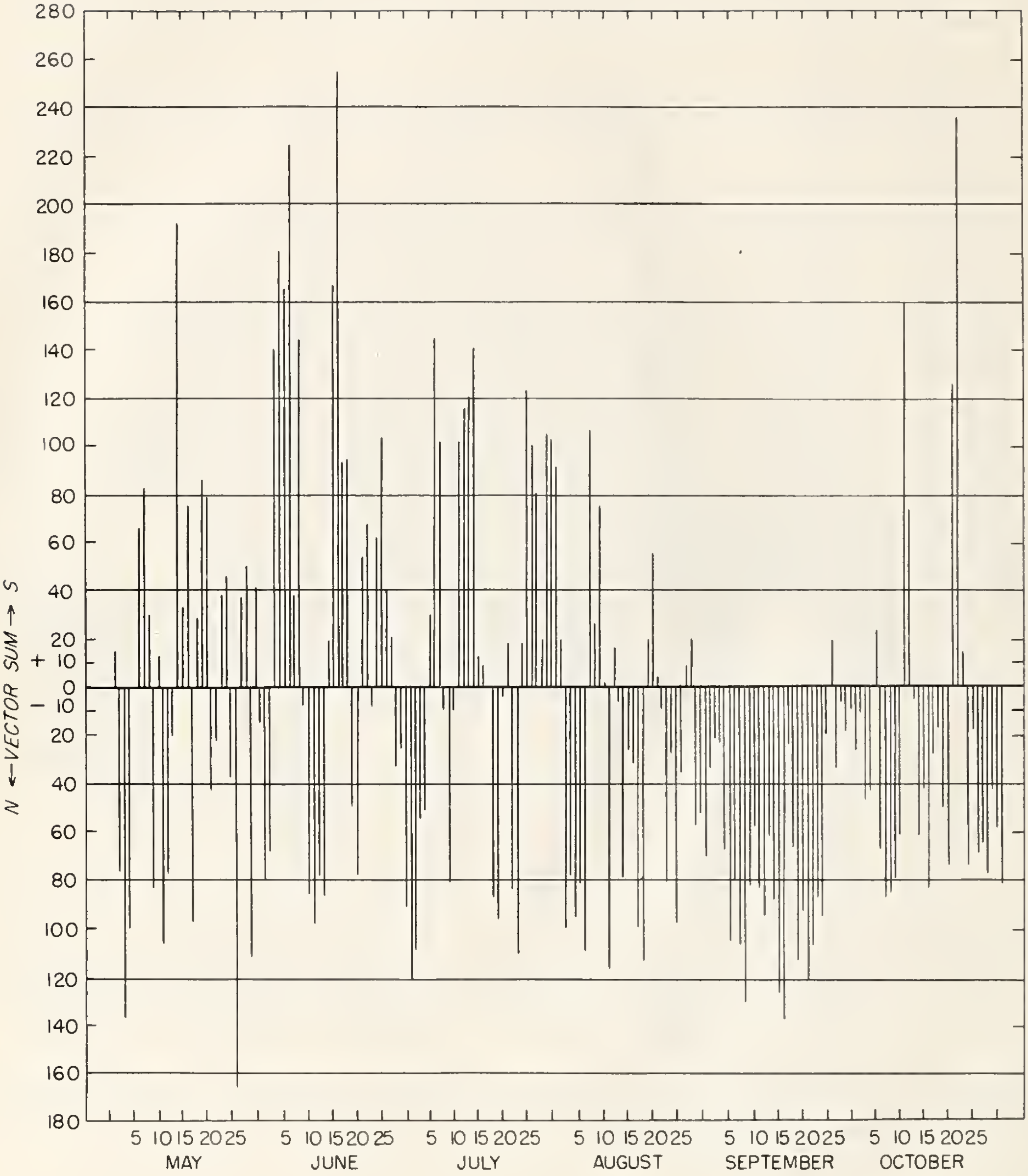

Figure 12.--Algebraic sum of hourly north-south wind components at San Diego for 1953 season.

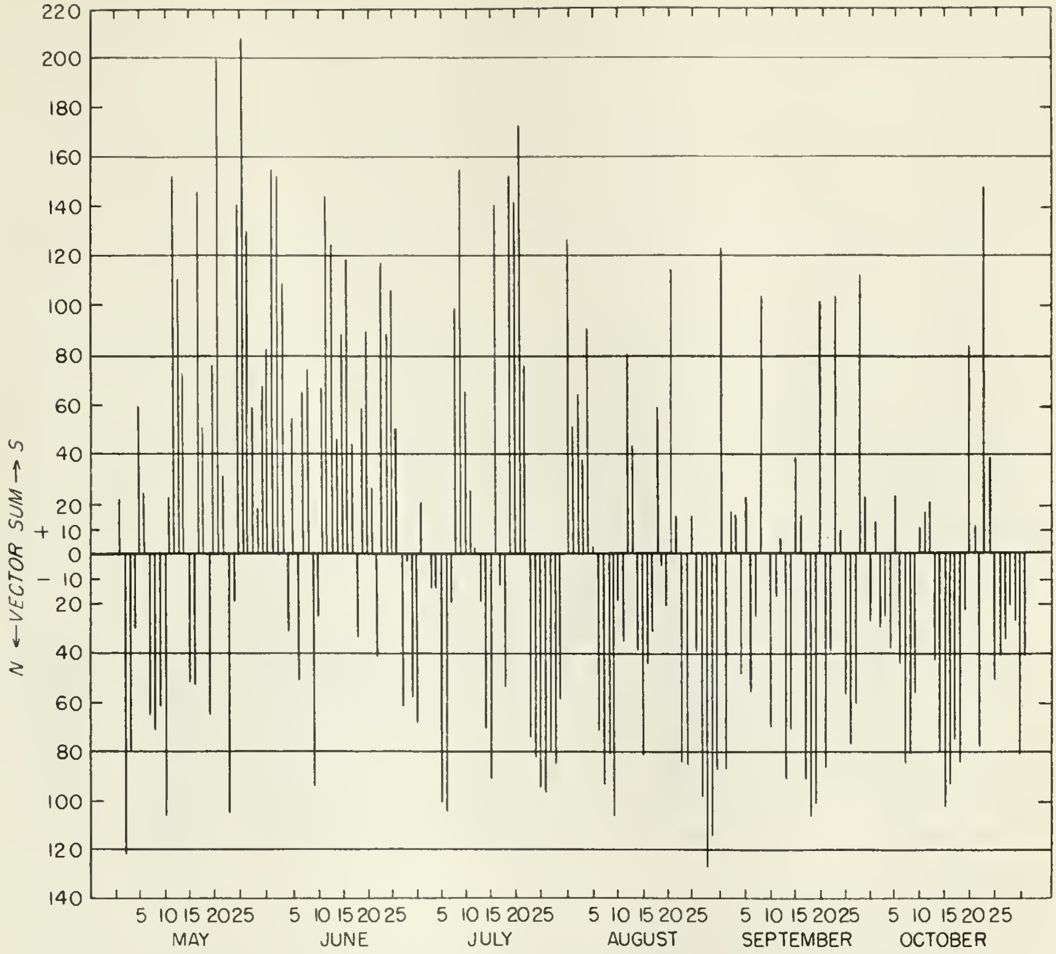

Figure 13.--Algebraic sum of hourly north-south wind components at San Diego for 1954 season.

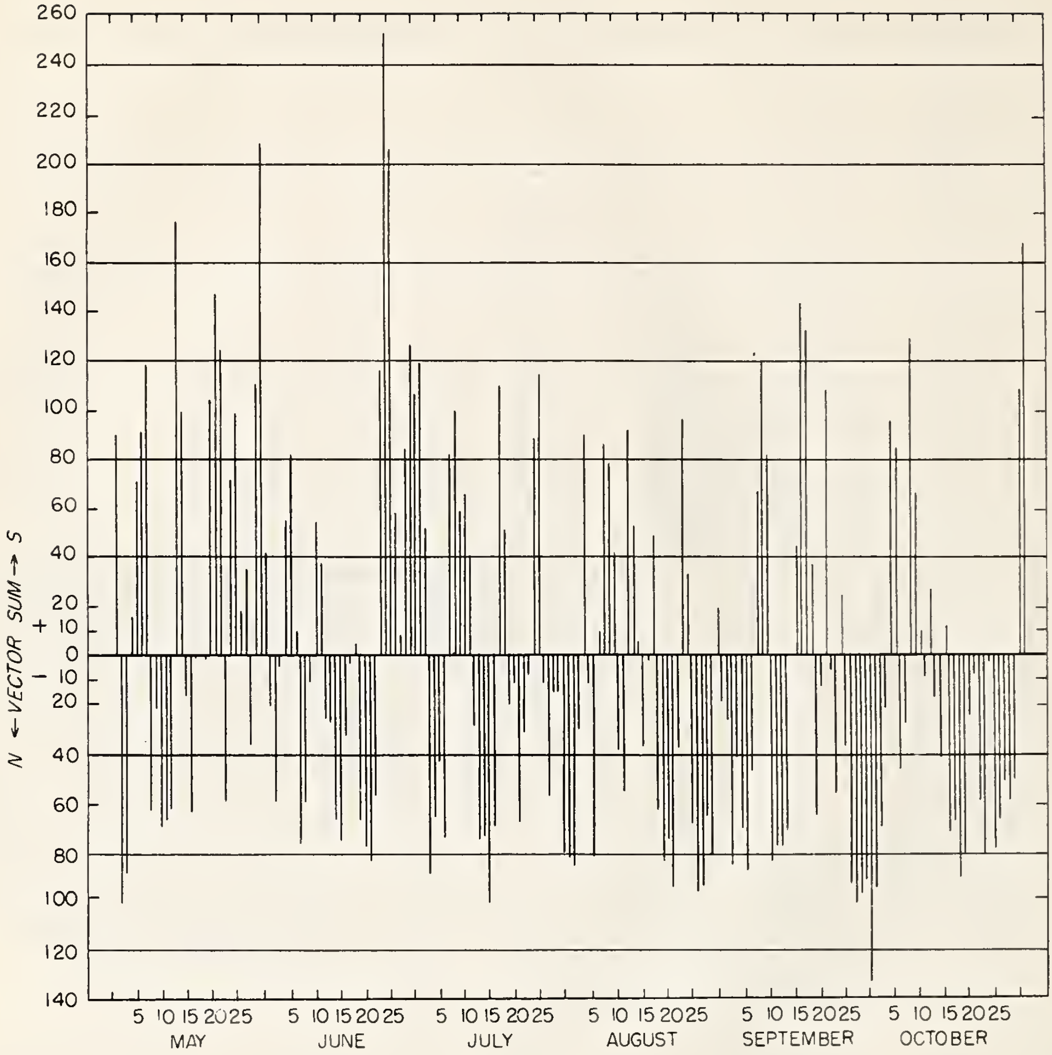

Figure 14.--Algebraic sum of hourly north-south wind components at San Diego for 1955 season.

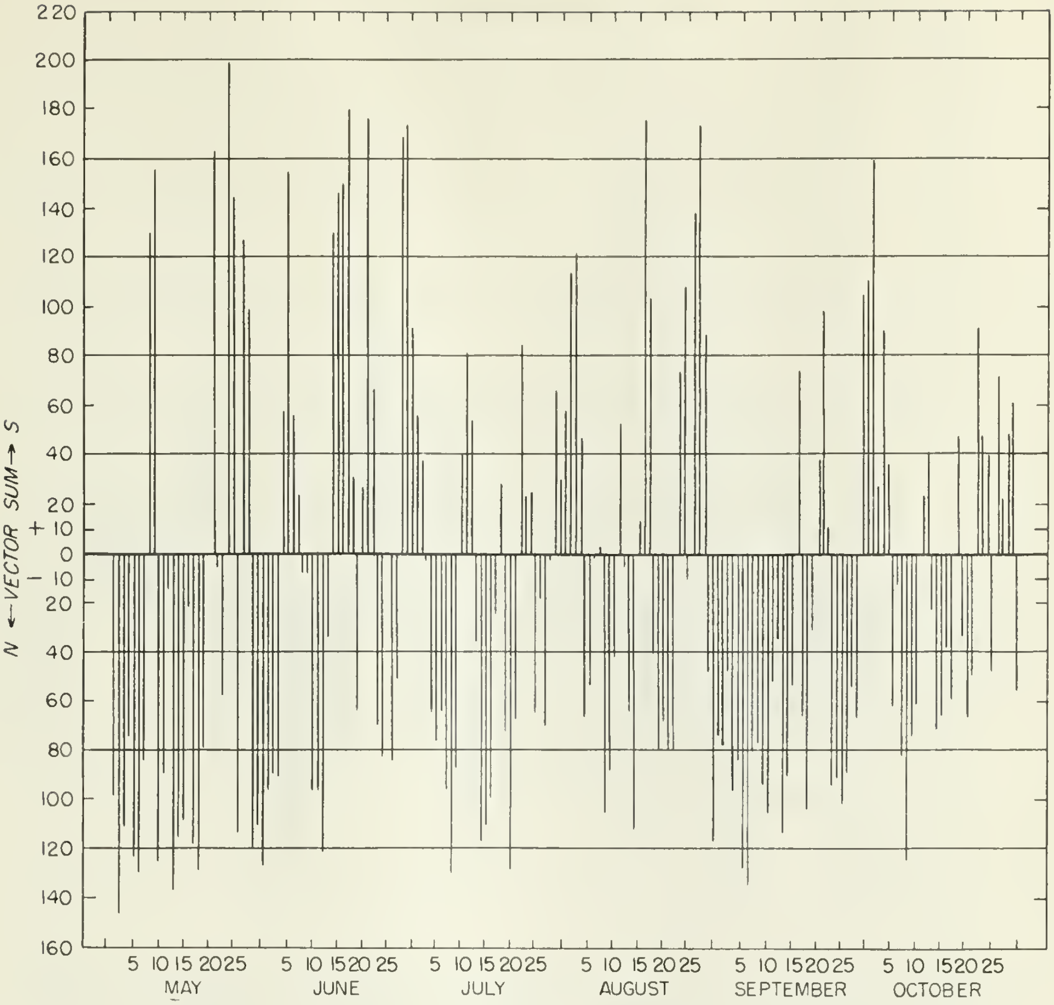

Figure 15.--Algebraic sum of hourly north-south wind components at San Diego for 1956 season.

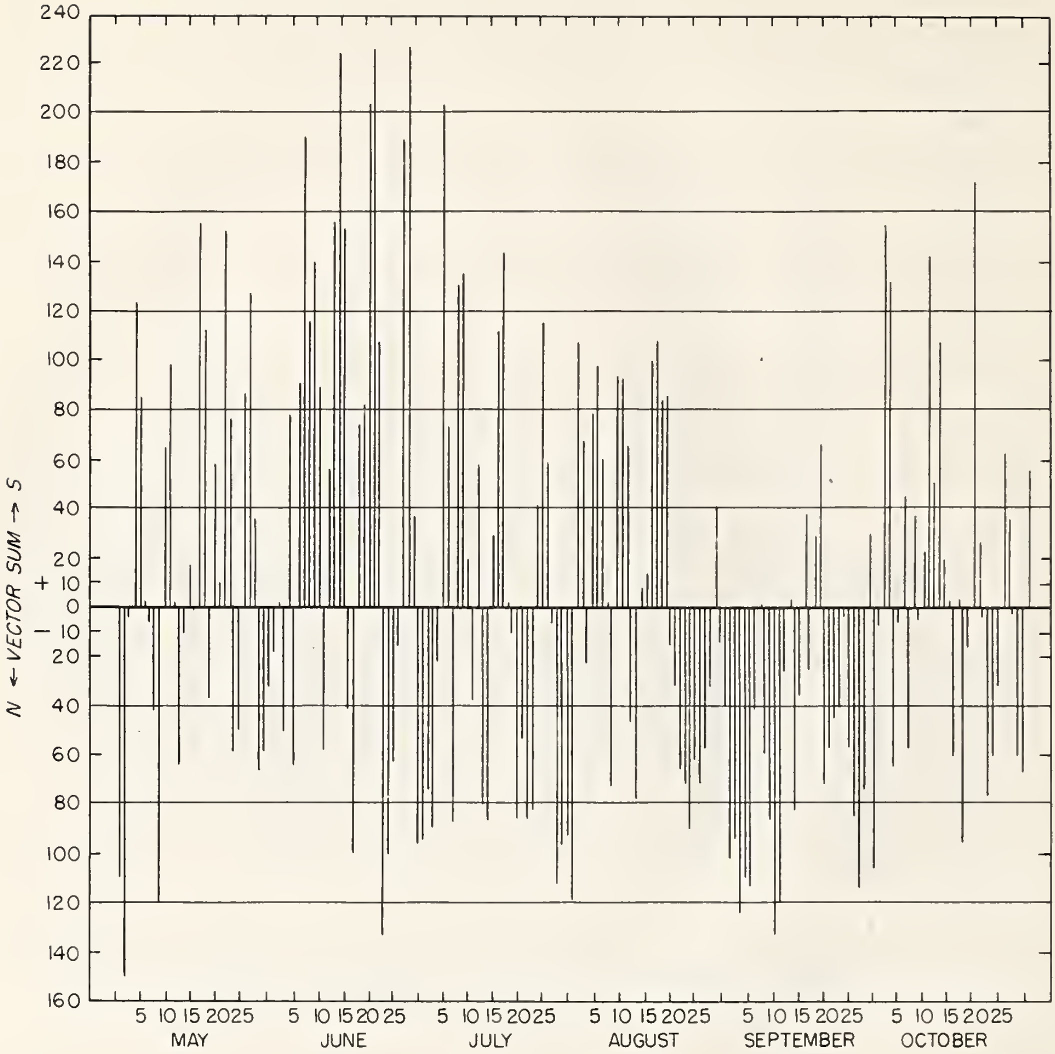

Figure 16.--Algebraic sum of hourly north-south wind components at San Diego for 1957 season.

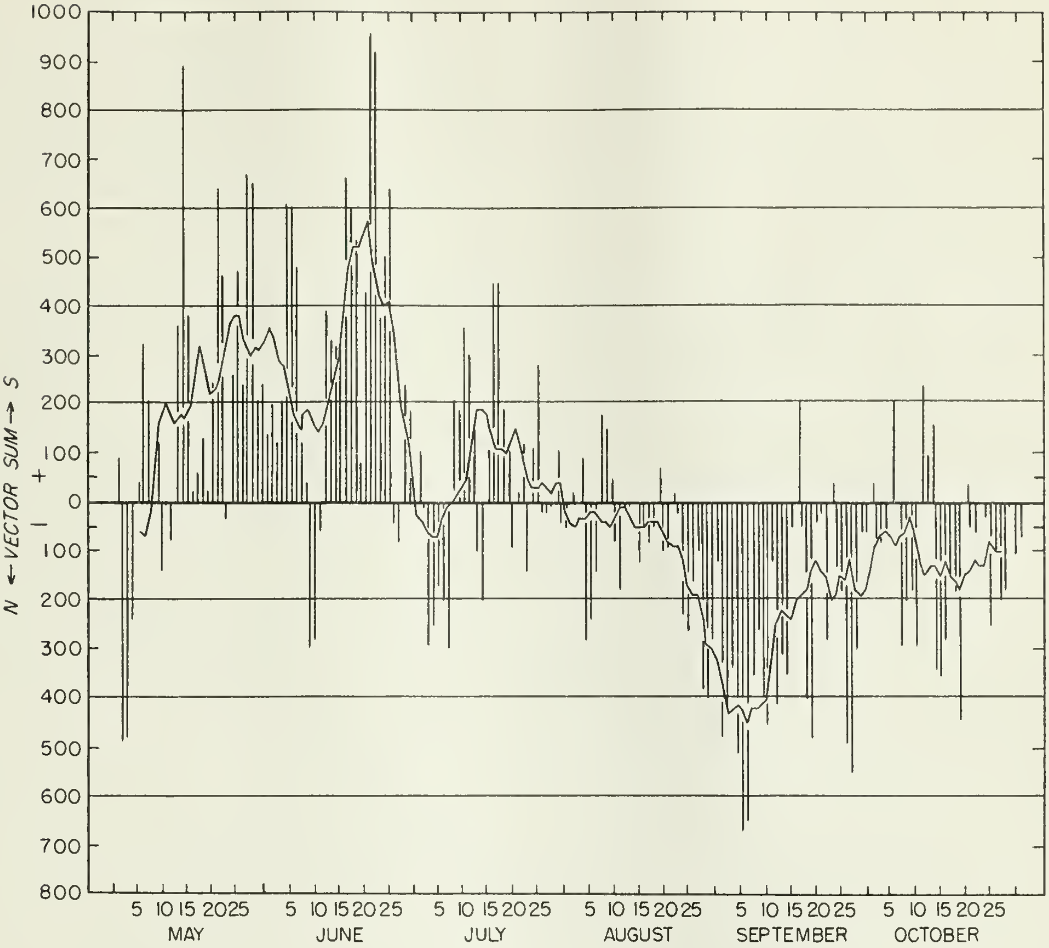

Figure 17.--Algebraic sum of daily north-south wind components at San Diego for 10-year period 1948-1957. Overlaid curve is 10-day moving mean.

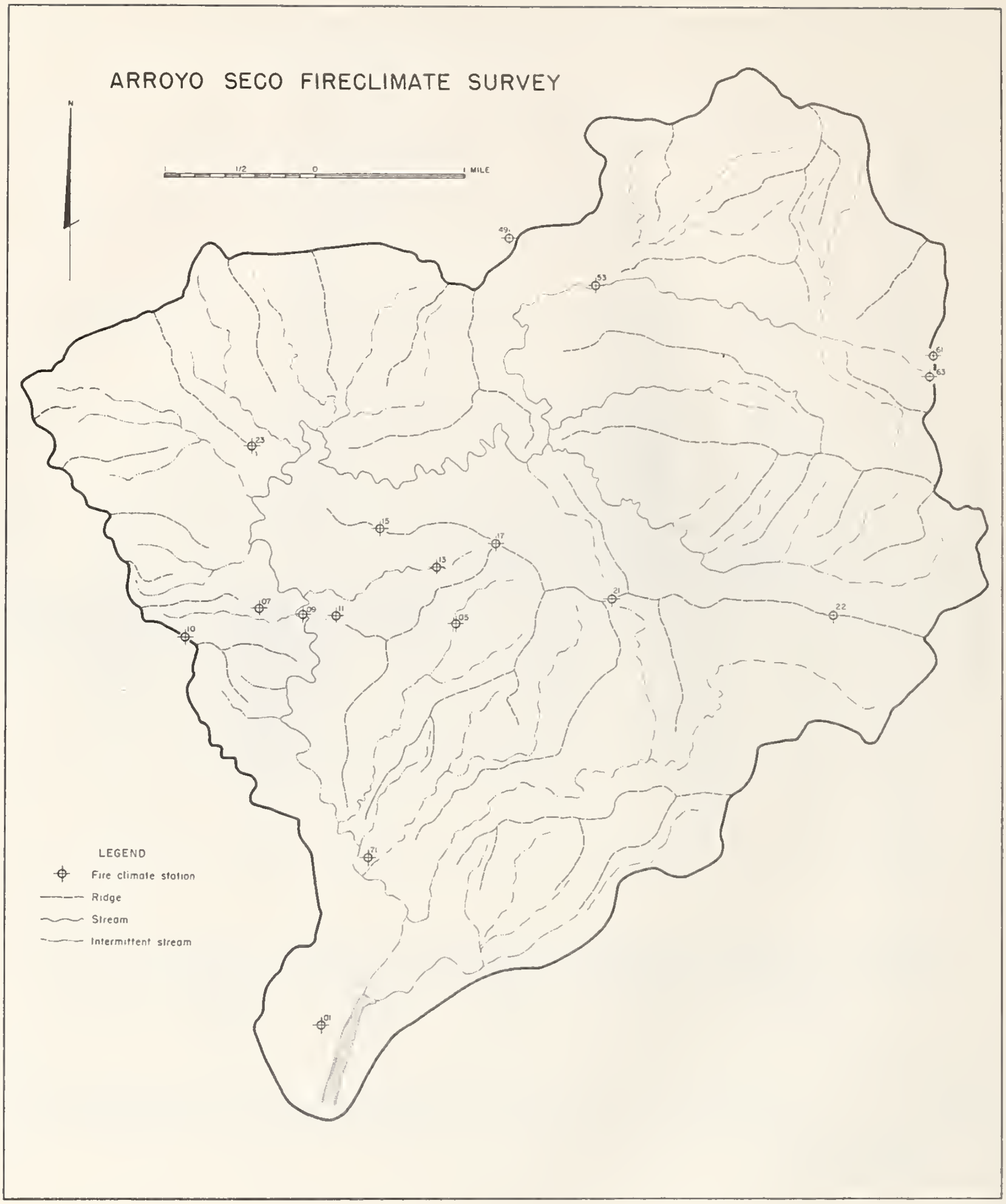

Figure 18.--Location of fireclimate stations in Arroyo Seco drainage.